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Indoor Parking Facilities Management Based on RFID CoO Positioning in Combination with Wi–Fi and UWB

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Project goals, objectives & vehicle localization support

Key objective

to develop a unified proposal for the management of large-scale parking facilities under constraints

- near-capacity demand,
- temporally constrained arrivals / departures,
- emergency evacuation situations (*under emergency conditions*)

methodological approach adopted relies

1

parking facilities modelling & simulation

- supply-side modelling
- driver behavior modelling
- model calibration

2

guidance and control

- guidance generation and response modelling
- traffic control and compliance modelling

3

undertake a pilot project

- integration
- validation
- evaluation

The need for vehicle localization data ⟺ key driver to the success of a project

localization support

1

parking facilities modelling & simulation

- supply-side modelling
- driver behavior modelling
- model calibration

2

guidance and control

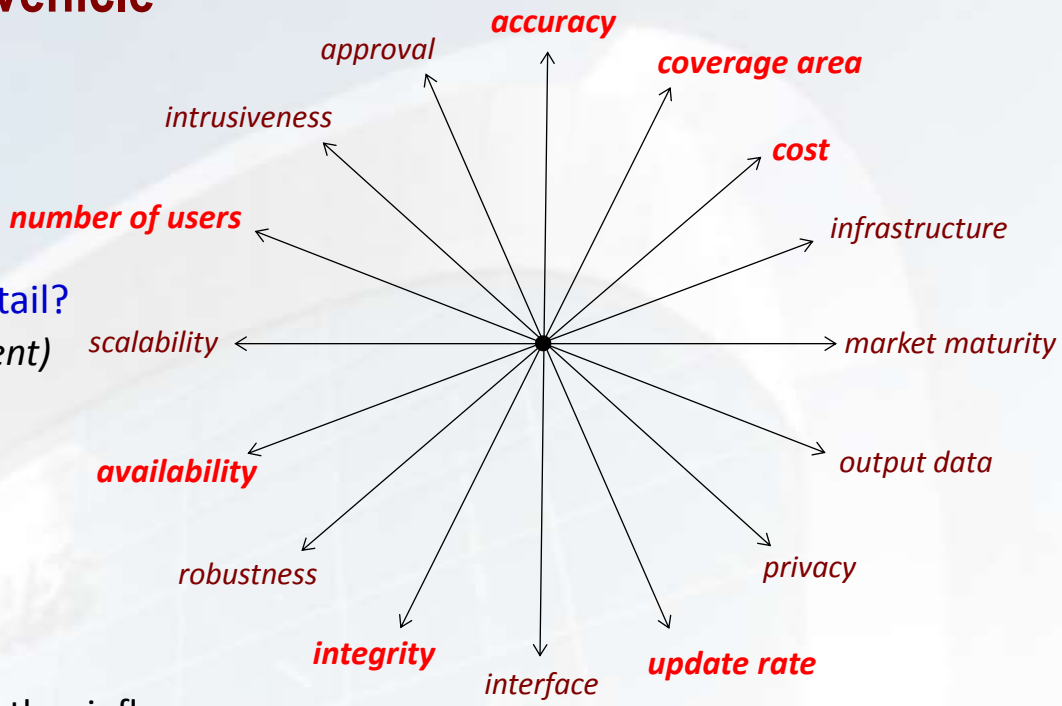
- guidance generation and response modelling
- traffic control and compliance modelling

3

testing through pilot project

- integration
- validation
- evaluation

What exactly is needed in terms of vehicle localization?



what user requirements to consider?

what parameters to compute? what level of detail?

- topology (*"vauge" position fix, direc. of movement)*
- kinematics (*velocity, acceleration, attitude, …*)
- position fix (*time stamped coordinates*)

other concerns to consider?

HYBRID & INDOOR ENVIRONMENT !!!

- ✓ severe multipath
- ✓ non-line-of-sight-conditions (NLoS)
- ✓ high attenuation & signal scattering
- ✓ fast temporal changes
- × low weather influences
- × fixed geometric constraints
- × good infrastructure (electricity, internet access, …)
- × lower dynamics

To attempt an answer, the starting point for all group members …

Transportation Engineers, *Geodetic Engineers* and *Electrical & Computer*

↓

establish a "common language" due to multi-disciplinary approach

↓

fully understand the requirements and constraints of the problem

↓

combine expertise

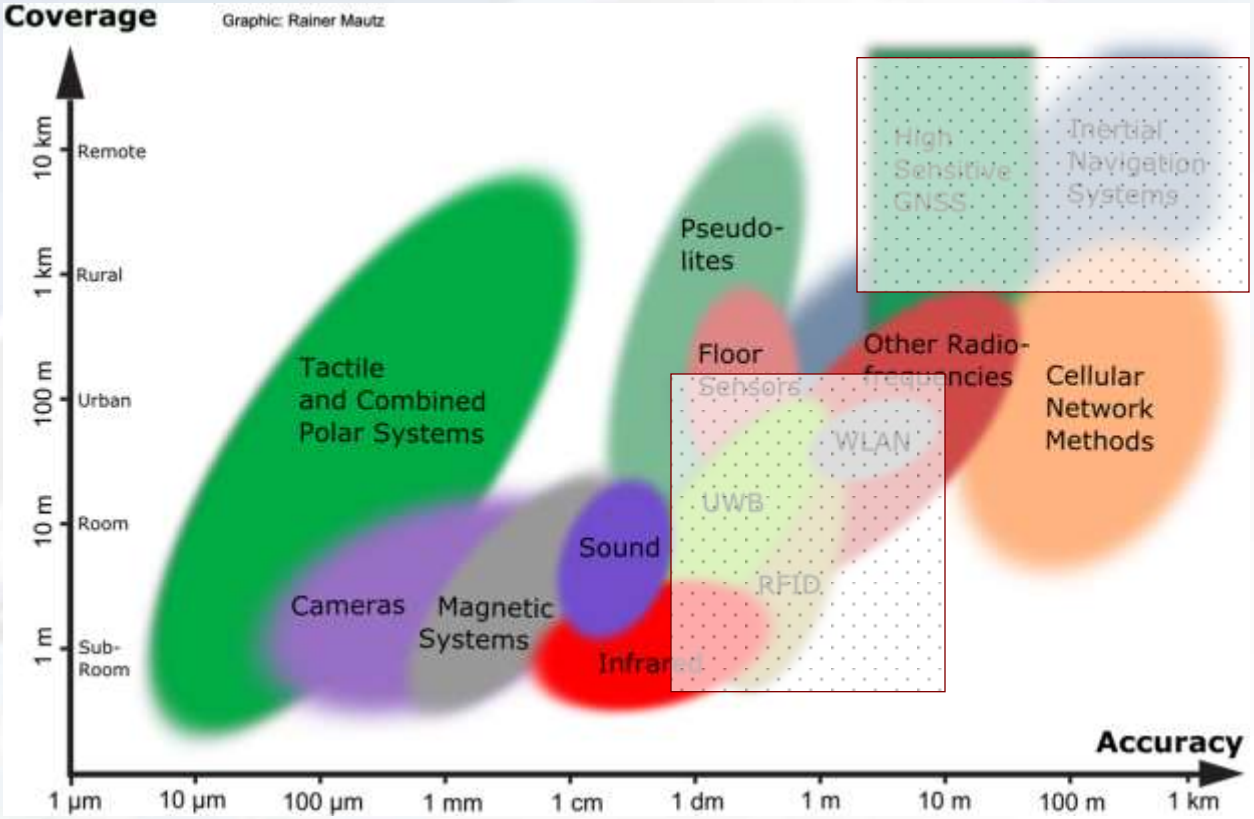
move indoors !

Overview of available indoor positioning technologies

many parameters to consider …

- accuracy
- availability
- coverage
- output rate
- data analysis requirements
- potential for integration
- …

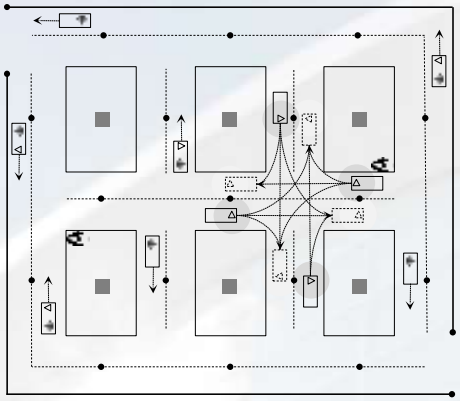
COST !



Four types of positioning technologies are considered

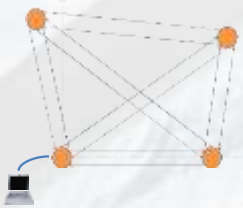
VEHICLE LOCALIZATION
topology & position fixing

RFID & Wi-Fi



DRIVER BEHAVIOR IDENTIFICATION
acceleration distribution

Smartphone MEMS-IMU



UWB

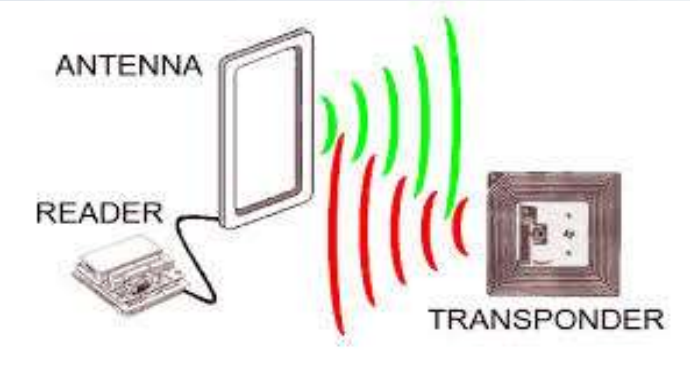
controlling of navigation solution hybrid & indoors

GNSS / IMU

Localization tools considered in this study: RFID and WLAN (WiFi) tools

RFID, Wi-Fi:

- used for data transmission between a WiFi / RFID tag and a WiFi / RFID reader
- logistics, asset management, etc.



data types:

- unique tag ID: indication of location
- Receiver Signal Strength: coarse range estimation

within EMPARCO:

seek low-cost localization solution

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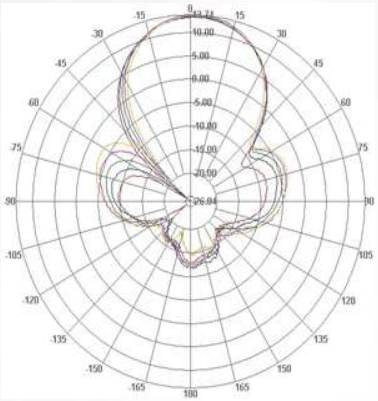
tag ID & CoO technique + Wi-Fi RSS

↓

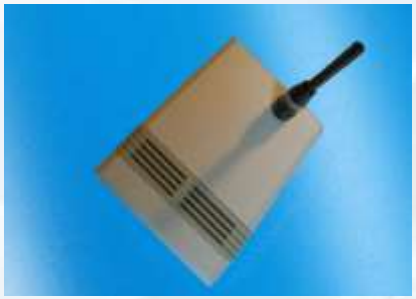
combined RFID and Wi-Fi positioning solution



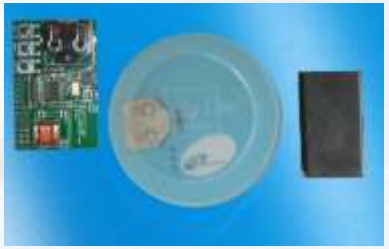
Wi-Fi and RFID equipment used includes

Sensor type	Sensor model	Raw measurements
Wi-Fi - Bluetooth Readers	Libelium Meshlium Scanner	MAC address, RSS (db)
RFID	Freaquent HTEV600 (readers) Freaquent ETS (tags)	TagID, 3D RSS (db)

Low cost system



Freaquent TEV600 (reader)



Freaquent ETS (tag)

Libelium Meshlium Scanner

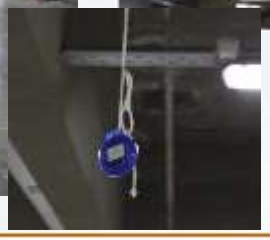
Parking spot and experimental scenarios

- layout of the parking spot and monitoring sensors placement
- experiments were undertaken at two levels logistics, asset management, etc.

Scenario	Number of vehicles	Environment	Goal
S-1.1	1	Hybrid	Indoor/ Outdoor environment transition
S-1.2	1	Indoor	Floor level changing recognition
S-2	2	Indoor	Dual vehicle trajectories recognition
S-3	10	Indoor	Multiple vehicles trajectories recognition

so far four preliminary test scenarios have been undertaken

Snapshots from data acquisition

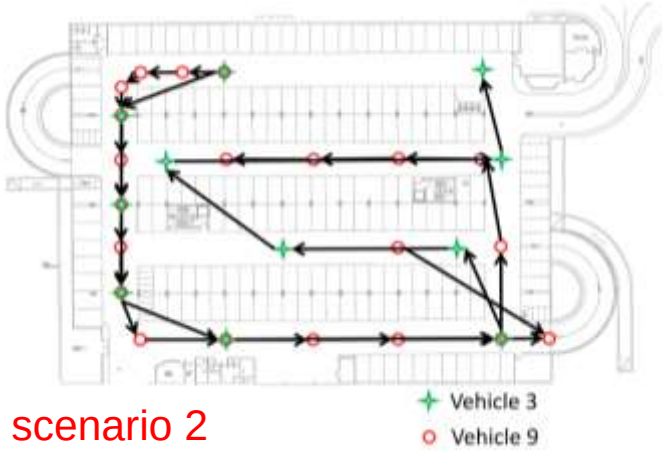


Outcome of the RFID CoO data processing and analysis

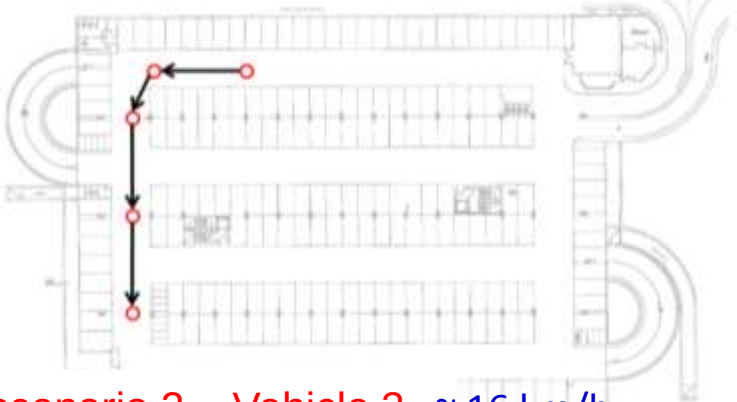
vehicles V3 and V9 for scenario 2

the trajectory of for V9 is more representative of the actual trajectory compared to the one obtained for V3

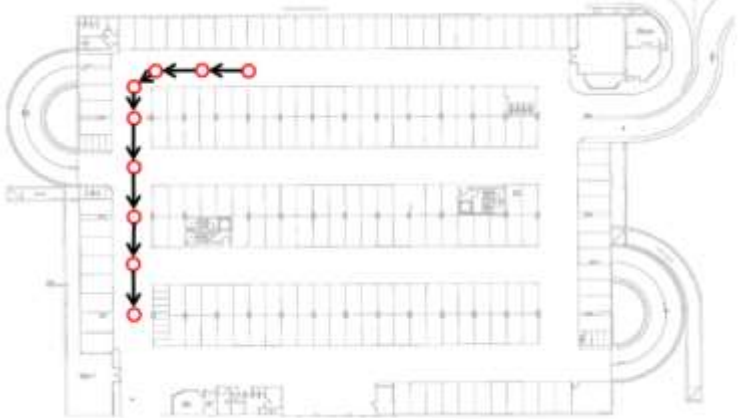
relates to the sampling frequency of RFID and vehicle velocity



scenario 2



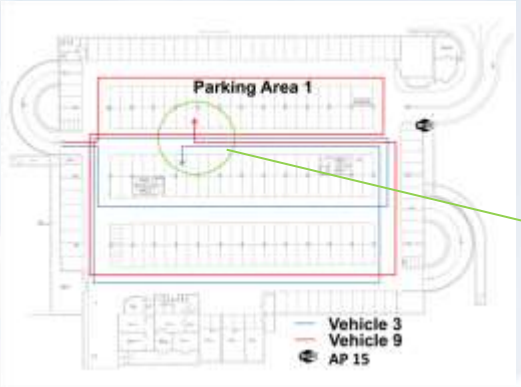
scenario 2 – Vehicle 3 ~ 16 km/h

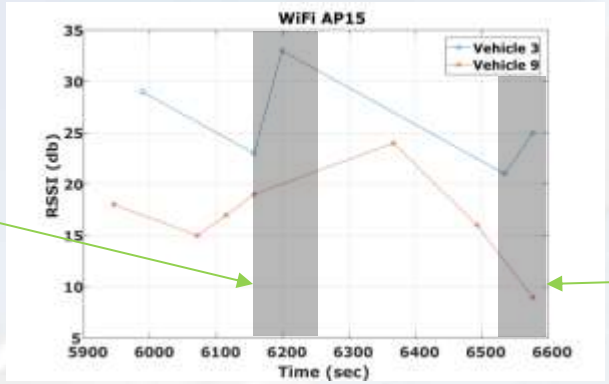


scenario 2 – Vehicle 9 ~ 9 km/h

Wi-Fi RSS values recorded from the smartphones placed on V3 and V9

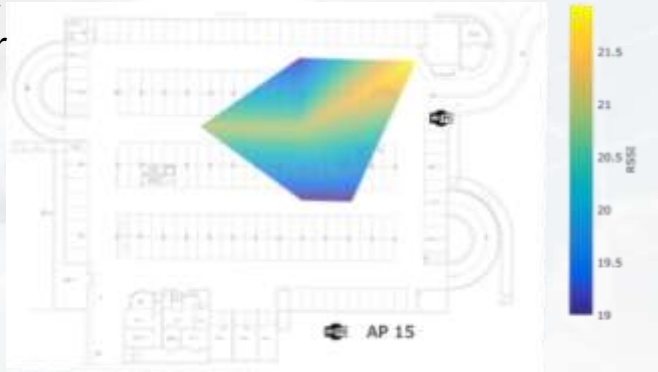
multipath effects → degrade RF signal propagation → RSS-distance models / lateration ???





Also, the Wi-Fi RSS radio maps were generated for the respective RFID positions for vehicles V3 & V9

Despite the low resolution, Wi-Fi fingerprinting appears to be a viable solution for complementing an RFID-based positioning solution

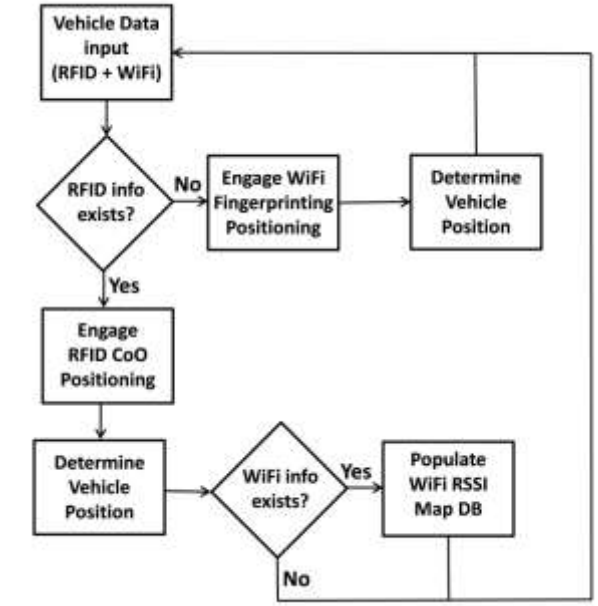


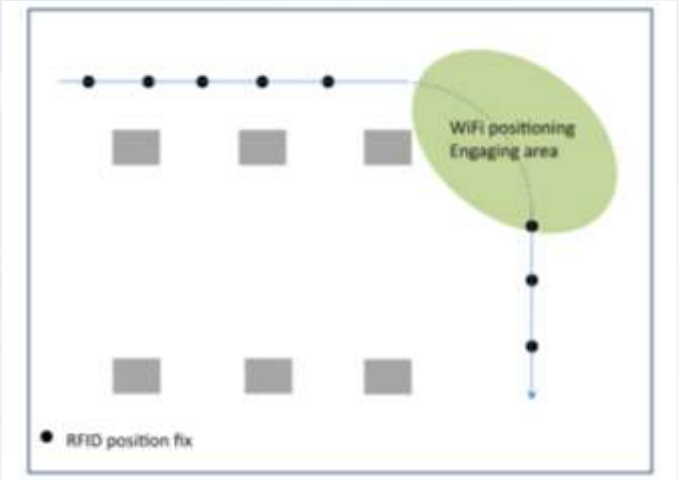
Voronoi Interpolation

combined RFID CoO and Wi-Fi dynamic fingerprinting solution for positioning indoors

RFID CoO positioning

- provides the primary positioning information
- a reference for Wi-Fi fingerprinting training
- in case of missing RFID position fixing Wi-Fi activates to close the gap





Wi-Fi fingerprinting positioning

- a training phase for Wi-Fi fingerprinting training is required
- Wi-Fi RSS values are associated to RFID locations for training the system
- WiFi positioning provides solution in cases of RFID CoO positioning absence

Summary and Outlook

preliminary results from an RFID CoO and Wi-Fi fingerprinting positioning concept for indoor parking facilities management

- RFID CoO algorithm has shown a tag detection success rate 70%-90%
- the low data sampling rate may result in a very sparse vehicle trajectory

on the other hand …

- Wi-Fi RSS-based fingerprinting appears to be a viable solution for complementing RFID-based positioning
- the low update rate and the requirement for a dense access point network make this option hard to implement.

- further investigation is needed to study the potential of a combined RFID / Wi-Fi-based solution using various approaches